**REMARKS/ARGUMENTS**

Claims 1, 5, 7, 11-14, 18-20 and 24-26 are currently pending in this application. Claims 13 and 26 have been allowed and claims 1 and 5 have been amended without addition of limitations to place them in better condition for allowance. In view of the above amendments and following remarks, applicants respectfully submit that the application is in condition for allowance. Applicants therefore respectfully request reconsideration and allowance of the application are therefore respectfully requested.

The Examiner rejected claims 1, 5, 7, 11, 14, 18, 20 and 24 under 35 U.S.C. 102(e) as allegedly being anticipated by Ziari et al. (U.S. Patent 6,522,756). Applicants respectfully traverse this rejection.

The present application claims priority to Japanese Patent Application 2000-182164 (the '164 application), filed June 16, 2000. Applicants respectfully submit that the '164 application (a verified translation of which is submitted herewith as Exhibit A) fully supports the subject matter claimed in the present invention. Applicants therefore respectfully submit that the currently pending claims are entitled to the filing date of the '164 application. Applicants further submit that Ziari et al., which has a filing date of October 24, 2000 which is after the effective filing date (June 16. 2000) of the present application is not prior art to the present application. Applicants therefore repectfully request that this rejection be withdrawn.

The Examiner rejected claims 12, 19 and 25 under 35 U.S.C. 103(a) as allegedly being obvious over Ziari et al. Applicants respectfully traverse this rejection. As argued above Ziari et al. is not prior art to the currently pending claims. Applicants therefore respectfully requests that this rejection be withdrawn.

The Examiner rejected claims 1, 5, 7, 11, 12, 14, 18-20 and 24-25 under 35 U.S.C. 103(a) as allegedly being unpatentable over Jain et al. (U.S. Patent 4,784,450) in view of Jones et al. DE 3,626,714. Applicants respectfully traverse this rejection.

Jain et al. relates to "wavelength or frequency shifting and amplification of optical radiation and more particularly to the use of polarization dependent four-wave-mixing processes to generate new wavelengths of optical radiation." (Jain et al. col. 1, lines 7-11). For example, in Jain et al. input radiation is launched "into both the fast and slow axis of a birefringent optical fiber waveguide. The two resulting pump waves interact in enhanced four photon mixing to produce Stokes and anti-Stokes waves along the slow and fast axis of the waveguide, respectively. The Stokes wave is the wave of primary interest and has a frequency shift on the order of 155 $cm^{-1}$ or less." (Jain et al., col. 2, line 64 - col. 3, line 4).

Thus the birefringement medium of Jain et al. (i.e. optical fiber 12 in FIGS. 1 and 3) is a non-linear optical element that provides four photon mixing (FPM) to generate optical radiation having a wavelength that is shifted from the wavelength of the optical pump or input radiation. In addition, Jones et al. discloses a dispersion element (BSMG) that simnply "reduces

unwanted signals caused by interference between the transmitted and received signals."

By way of contrast, independent claims 1, 5, 7, 11, 14, 18, 20 and 24 recite "a degree-of-polarization reducer comprising a birefringent medium to reduce a degree of polarization of the light ..." Applicants respectfully submit that the cited references alone or incombination do not disclose or suggest the recited limitation. Accordingly, applicants further submit that independent claims 1, 5, 7, 11, 14, 18, 20 and 24 are novel and unobvious over the cited references and are therefore allowable. Applicants further submit that claims 12, 19 and 25 that depend from claims 7, 14 and 20 respectively are allowable as are claims 7, 14 and 20 and for additional limitations recited therein.

With respect to independent claims 5, 11, 18 and 24 the Examiner admits that Jain et al. does not explicitly teach that the birefringent optical waveguide has a polarization dispersion longer than the coherence of the output light from each of the pumping light sources. The Examiner alleges however that Jones et al. discloses a dispersion elment for a pump source using a polarized light in which the polarization dispersion is longer that the coherence length of the optical light source. The Examiner notes that Jones et al. teaches that having the polarization dispersion longer than the coherence length reduces interference between the sent/received signals.

The Examiner therefore alleges that it would have been obvious at the time the invention was made to a person having ordinary skill in the art to use a dispersion element having the

polarization dispersion greater than the coherence length of the source as taught by Jones et al. in the system of Jain et al. to reduce unwanted signals caused by interference in a pumping light source. Applicants respectfully traverse this rejection.

The combination of references in an obviousness rejection must be based upon a clear and particular showing of a teaching or motivation to combine those prior art references. As noted by the Examiner Jones et al. utilizes a birefringent medium having a polarization dispersion longer than the coherence length to reduce interference between the sent/received signals However, in Jain et al. the pumping lights interfere to generate optical radiation at a shifted wavelength.

For example, Jain et al. disclose that "two resulting pump waves interact in enhanced photon mixing to produce Stokes and anti-Stokes waves along the slow and fast axis of the waveguide, respectively." (Jain et al., col. 2, line 67 - col. 3, line 2). Thus Jain et al. actually teaches away from the use of a birefringent medium to reduce interference . Accordingly, neither Jones et al. or Jain et al. provide any teaching, suggestion or motivation supporting the proposed combination disclosed by applicants. Applicants therefore respectfully submit that independent claims 5, 11, 18 and 24 are novel and unobvious over Jain et and Jones et al. and are therefore allowable.

**Appln No. 09/882,352**
**Amdt date September 9, 2003**
**Reply to Office action of** June 10, 2003

It is therefore respectfully submitted that pending claims 1, 5, 7, 11-14, 18-20 and 24-26 are in condition for allowance, and an early notice of allowance is respectfully requested.

Respectfully submitted,

CHRISTIE, PARKER & HALE, LLP

By ______________________________
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**DECLARATION**

I, Akiko Koyama, of c/o Tanaka Patent Office, Ogawa Bldg. 5th Floor, 32-2, Higashi-Ikebukuro 1-chome, Toshima-ku, Tokyo, Japan, hereby declare that I am well versed in English and Japanese languages, that I am the true translator of the officially certified copy of Japanese Patent Application No. 2000-182164 (attached herewith), and that the following is a true and correct translation to the best of my knowledge and belief.

Dated this 3rd day of September, 2003

A. Koyama

Akiko Koyama

Japanese Patent Application No. 2000-182164

[Title of Document] Specification

[Title of the Invention] PUMPING LIGHT GENERATOR AND FIBER RAMAN AMPLIFIER

[Scope of Claims for a Patent]

[Claim 1] A pumping light generator comprising:

two pumping light sources;

a combiner to combine pumping lights output from the two pumping light sources in orthogonal state of polarization; and

a degree-of-polarization reducer to reduce the degree of polarization of the light output from the polarizing beam combiner.

[Claim 2] The pumping light generator of claim 1 wherein the degree-of-polarization reducer comprises a depolarizing element to depolarize the output light from the combiner.

[Claim 3] The pumping light generator of claim 1 wherein the degree-of-polarization reducer comprises a birefringent medium.

[Claim 4] The pumping light generator of claim 3 wherein the birefringent medium is disposed so as to output each input pumping light from each polarization axis of the birefringent medium at practically equal optical power to other.

[Claim 5] The pumping light generator of claim 3 wherein the birefringent medium comprises polarization dispersion longer than a coherence length of the output light from each pumping light source.

[Claim 6] The pumping light generator of claim 3 wherein the birefringent medium comprises either one of rutile crystal and $YVO_4$.

[Claim 7] A pumping light generator comprising:

a plurality of pumping light sources;

a combiner to combine output lights from the plurality of pumping light sources; and

a degree-of-polarization reducer to reduce the degree of polarization of the light output from the combiner.

[Claim 8] The pumping light generator of claim 7 wherein the degree-of-polarization reducer comprises a depolarizing element to depolarize the output light from the combiner.

[Claim 9] The pumping light generator of claim 7 wherein the degree-of-polarization reducer comprises a birefringent medium.

[Claim 10] The pumping light generator of claim 9 wherein the birefringent medium is disposed so as to output each input pumping light from each polarization axis of the birefringent medium at practically equal optical power to the others.

[Claim 11] The pumping light generator of claim 9 wherein the birefringent medium comprises polarization dispersion longer than a coherence length of the light output from each pumping light source.

[Claim 12] The pumping light generator of claim 9 wherein the birefringent medium comprises either one of rutile crystal and $YVO_4$.

[Claim 13] The pumping light source of claim 7 wherein the degree-of-polarization reducer comprises the first and the second birefringent mediums in which each polarization dispersion is longer than a coherence length of the output light from each pumping light, one polarization dispersion differs twice as much as the other one, and the second birefringent medium is arranged behind the first birefringent medium and the first and second birefringent mediums are deposited so that the light passed through the first birefringent medium is output from two polarization axes of the second birefringent medium at almost the equivalent optical power.

[Claim 14] A fiber Raman amplifier comprising:

a pumping light generator of any one of claims 1 through 6;

an optical fiber to transmit a signal light; and

an optical coupler to couple the light output from the pumping light generator with the optical fiber.

[Claim 15] A fiber Raman amplifier comprising:

a pumping light generator of any one of claims 7 through 13;

an optical fiber to transmit a signal light; and

an optical coupler to couple the light output from the pumping light generator with the optical fiber.

[Detailed Description of the Invention]

[Technical Field of the Invention]

This invention relates to a pumping light generator and fiber Raman amplifier, and more specifically to an apparatus to generate a pumping light for optical amplification and a fiber Raman amplifier

to use the pumping light generator.

[Prior Art]

Recently, fiber Raman amplifiers have received much attention as important optical amplification technology to solve a lack of amplification bands in future ultra large capacity optical transmission systems because it is capable of using any wavelength band as an amplification band by choosing an appropriate pumping light wavelength.

In the fiber Raman amplification, in principle, gain becomes the maximum when the state of polarization of the pumping light agrees with that of the signal light and the gain becomes zero when the state of polarization of the pumping light is orthogonal to that of the signal light. Therefore, in order to obtain a constant gain regardless of the state of polarization of the signal light, it is necessary to depolarize the pumping light.

To depolarize the pumping light, such a configuration as shown in FIG. 4 is well known (US Pat. 4,805,977). Two laser diodes (pumping light sources) 10 and 12 output pumping lights of constant polarization, having no or small interrelation each other. A polarizing beam splitter 14 combines the output lights from the laser diodes 10 and 12 at almost equal optical power and in orthogonal state of polarization.

In addition, a method to depolarize the light with a birefringence medium or Lyot depolarizer is also widely known (See Japanese Laid-Open Patent Publication No. 59-155806 (US Pat. 4,572,608), Japanese Laid-Open Patent Publication No. 57-190922, William K burns, "Degree of Polarization in the Lyot Depolarizer", Journal of Lightwave Tcchnology, Vol. LT-1, No. 3, pp. 475-479, September 1983, and Kiyofumi Mochizukim, "Degree of polarization in jointed fibers: the Lyot depolarizer", Applied Optics, Vol. 23, No. 19, pp. 3284-3288, 1 October 1984).

Furthermore, the use of wavelength-division-multiplexed depolarized pump light has been proposed for depolarized pump light source with some source redundancy (Y. Emori, S. Matsushita, and S.

Namiki, "Cost-effective depolarized diode pump unit designed for C-band flat-gain Raman amplifiers to control EDFA gain profile", Tcchnical Digest, OFC2000, paper FF4, 2000). FIG. 5 shows a schematic block diagram of such a pumping light generator.

In FIG. 5, a laser diode (a pumping light source) 20a outputs a completely polarized light (or a highly polarized light) having a wavelength of 1428 nm, and a laser diode (a pumping light source) 20b outputs a completely polarized light (or a highly polarized light) having a wavelength of 1455 nm. The lights output from the laser diodes 20a and 20b are depolarized by passing through high birefringent optical fibers (or polarization holding fibers) 22a and 22b respectively and combined by a combiner 24. The light output from the combiner 24 contains the lights of the wavelengths 1428 nm and 1455 nm and are being depolarized or weakly-polarized.

[Problems to be Solved by the Invention]

In the conventional configuration shown in FIG. 4, the depolarized pumping light sources of high-output are realized because it is possible to combine two pumping lights of the same wavelength band at low-loss. However, if one of the pumping light sources has failure, the output light becomes a completely polarized light causing a fiber Raman amplifier to have severe polarization dependency.

In the conventional configuration shown in FIG. 5, since a pumping light of each wavelength is separately depolarized, the degree of polarization of the light output from the combiner 24 will never changes even if any one of pumping light sources has failure. However, in this configuration, since polarization combination to combine pumping lights at low-loss cannot be used, it is difficult to increase pumping light power in the same wavelength band. In addition, if any one of the pumping light sources of the respective wavelength has failure, gain wavelength characteristics (gain shape) of the fiber Raman amplifier are severely changed since this particular pumping wavelength component is absent.

It is therefore an object of the present invention to provide a pumping light generator which solves the above-described problems.

Another object of the present invention is to provide a pumping light generator in which output power is easily increased.

A further object of the present invention is to provide a pumping light generator which can be realized with fewer elements and outputs a pumping light of high intensity in a depolarized or weakly-polarized state.

Still a further object of the present invention is to provide a pumping light generator in which output light is kept in a depolarized or weakly-polarized state even if one of pumping light sources has failure.

[Means for Solving the problem]

A pumping light generator according to the invention is composed of two pumping light sources, a combiner to combine the pump outputs from the two pumping light sources in orthogonal state of polarization, and a degree-of-polarization reducer to reduce the degree of polarization of the light from the polarizing combiner.

With this configuration, a single degree-of-polarization reducer can reduce each degree of polarization of the two pumping lights combined in orthogonal state of polarization simultaneously. Accordingly, if one of the pumping light sources has a failure, the degree of polarization of the pumping light output from the generator does not increase and thus it is possible to maintain high reliability.

Also, the pumping light generator according to the invention is composed of a plurality of pumping light sources, a combiner to combine lights output from the plurality of pumping light sources, and a degree-of-polarization reducer to reduce the degree of polarization of the light output from the combiner.

This configuration makes it possible that a single degree-of-polarization reducer can reduce the degree of polarizations of the plurality of pumping lights collectively. Accordingly, a simple, compact, and economical pumping light generator can be realized.

Preferably, the degree-of-polarization reducer contains a depolarizing element to depolarize the light output from the combiner.

The degree-of-polarization reducer consists of, for example,

a birefringent medium. The birefringent medium is disposed so that it outputs each input pumping light from each polarization axis of the birefringent medium at practically equal optical power to the others. The birefringent medium has polarization dispersion longer than a coherent length of the output light from each pumping light source. The birefringent medium contains for example rutile crystal or $YVO_4$.

The degree-of-polarization reducer is composed of the first and the second birefringent mediums in which each polarization dispersion is longer than a coherence length of the output light from each pumping light source, one polarization dispersion differs more than twice as much as the other one, and the second birefringent medium is arranged behind the first birefringent medium and the first birefringent medium and the second birefringent medium are disposed so that the light passed through one polarization axis of the first birefringent medium is output from two polarization axes of the second birefringent medium at almost equivalent optical power. By using this configuration, it is also possible to utilize a polarization non-maintaining type combiner.

A fiber Raman amplifier according to the invention is composed of the above-mentioned pumping light generator, an optical fiber to transmit a signal light, and an optical coupler to couple an output light from the pumping light generator with the optical fiber.

[Mode for Embodying the Invention]

Embodiments of the invention are explained below in detail with reference to the drawings.

FIG. 1 shows a schematic block diagram of the first embodiment according to the invention. Reference numerals 30a and 30b denote laser diodes (pumping light sources) to generate the laser light having a high degree of polarization, more specifically, Fabry-Perot laser diodes (FP-LD) made of InGaAsP which oscillate at 1480 nm band. The outputs from the laser diodes 30a and 30b enter a polarizing beam splitter 32 in orthogonal state of polarization with each other and are combined together there. The outputs from the laser diodes 30a

and 30b are combined at low-loss because of this polarization combination. Oscillation wavelength bands of the laser diodes 30a and 30b can be practically the same or different. The light combined by the polarizing beam splitter 32 enters a depolarizing element 34 and is depolarized there. The laser diodes 30a and 30b, the polarizing beam splitter 32 and the depolarizing element 34 form a pumping light generator 36 of this embodiment.

The depolarizing element 34 is composed of, for example, birefringent crystal such as rutile crystal, and it is disposed so that its birefringent axis meets each polarization axis of the polarizing beam splitter 32 at an angle of 45°. With this configuration, optical powers output from the respective polarization axes are almost unified and accordingly the output light from the rutile crystal becomes depolarized light. If transmission loss of the rutile crystal differs in each birefringent axis, the disposition angle for the polarization bean splitter 32 should be adjusted so that the optical powers output from the respective birefringent axes become equivalent. The laser diodes 30a and 30b are generally multi-mode oscillating, and their light source spectrum widths are approximately as wide as 10 nm. This means that the coherence time is about 1 ps. When the rutile crystal is longer than 1 mm, the polarization dispersion can be obtained approximately more than 1 ps and thus it is practically possible to realize depolarization.

The light from the pumping light generator 36, namely the output light from the depolarizing element 34 enters an optical coupler 38. The optical coupler 38 introduces the pumping light output from the pumping light generator 36 into an optical fiber transmission line 40 in the opposite direction from the propagation direction of the signal light, for example. On the optical fiber transmission line 40, the pumping light from the pumping light generator 36 causes Raman amplification and the signal light is amplified.

In the embodiment shown in FIG. 1, since the output lights from the two laser light sources are depolarized simultaneously by one depolarizing element after polarization combination, even if one of the laser light sources has a failure, the degree of polarization

of the output light from the generator 36 will not increase. Accordingly, a pumping light generator with robustness against failure is realized. The output powers from the laser diodes 30a and 30b can be used effectively because it is possible to utilize the polarization combination.

FIG. 2 shows a schematic block diagram of the second embodiment according to invention. Reference numerals 50a and 50b denote laser diodes (pumping light sources) to generate a laser light having a high degree of polarization. The laser diodes 50a and 50b are, more specifically, composed of laser diodes made of InGaAsP which oscillation wavelength is stabilized to 1460 nm and 1480 nm by such as an outside fiber grating respectively. Output lights from the laser diodes 50a and 50b enter a polarization maintaining type combiner 52. The combiner 52 combines the output lights from the laser diodes 50a and 50b in maintaining both state of polarizations of the output lights and applies the combined light to a depolarizing element 54. The output light from the combiner 52, namely the input light of the depolarizing element 54 is being polarized in two directions according to the original output lights of the laser diodes 50a and 50b, and the depolarizing element 54 depolarizes those component lights together. The laser diodes 50a and 50b, the combiner 52 and the depolarizing element 54 form a pumping light generator 56 of this embodiment.

The depolarizing element 54 is composed of, similarly to the depolarizing element 34, birefringent crystal such as rutile crystal, for example. Since laser oscillating spectrum widths of the laser diodes 50a and 50b are as narrow as approximately 1 nm, the coherence time is about 10 ps. Accordingly, when the rutile crystal used for the depolarizing element 54 is about 10 mm long, the polarization dispersion is about 10 ps and thus it is practically possible to realize depolarization.

The output light from the pumping light generator 56, namely the output light from the depolarizing element 54, enters an optical coupler 58. The optical coupler 58 introduces the pumping light output from the pumping light generator 56 into an optical fiber

transmission line 60 in the opposite direction from a propagation direction of the signal light, for example. On the optical fiber transmission line 60, the pumping light from the pumping light generator 56 causes Raman amplification, and the signal light is amplified.

In the embodiment shown in FIG. 2, the polarization maintaining type combiner 52 combines main lights from the plurality of pumping light sources, the single depolarizing element 52 depolarizes the combined lights collectively, and therefore a pumping light generator of simple and small configuration is realized with low cost.

In the embodiment shown in FIG. 2, the polarization maintaining type combiner 52 is used. However, a combiner which cannot maintain polarization is also applicable. If such a combiner is utilized, the depolarizing element 54 should be prepared as follows. That is, as shown in FIG. 3, birefringent mediums 62, 64 are connected in serial which polarization dispersions are longer than the coherence lengths of the output lights from the laser diodes 50a, 50b and in which one polarization dispersion differs more than twice as much as the other one. The two birefringent mediums 62 and 64 should be disposed so that the light passed through one polarization axis of the first located birefringent medium 62 is output from two polarization axes of the latter birefringent medium 64 at almost identical optical powers. When transmission loss of the rutile crystal is uniform at every birefringent axis, 10 mm rutile crystal and 20 mm rutile crystal should be disposed so that each birefringent axis is inclined at 45°.

Birefringent mediums to be used as the depolarizing elements 34 and 54 are high birefringent optical fiber such as a PANDA fiber (a trademark) and $YVO_4$ besides the rutile crystal.

It is also applicable to combine the embodiments in FIG. 1 and 2. For example, it is possible to use the light source to combine output lights from a plurality of pumping light sources at the same wavelength band in the orthogonal state of polarization and output them instead of the laser diode 50a. The laser diode 50b is also in the same situation.

In the above description, the depolarizing elements 34 and 54

are explained as depolarizing the input light, it is also possible that they only reduce the degree of polarization of the input light. The more the degree of polarization is reduced, the more the optical amplification characteristics is stabilized.

[Effect of the Invention]

As readily understandable from the aforementioned explanation, according to the invention, since a plurality of pumping lights are combined first and depolarized or weakly-polarized all at once, depolarized state of the pumping lights can be maintained even if one of the pumping light sources has failure. By using this configuration, an optical amplifier, e.g. a fiber Raman amplifier, which is highly reliable, economical and highly efficient is realized. In addition, it is possible to obtain depolarized or weakly-polarized combination pumping lights from a plurality of pumping lights having a different wavelength using a simple configuration. Therefore, this invention can largely contribute to increase channel capacity in optical fiber communication networks.

[Brief description of Drawings]

[FIG. 1] A schematic block diagram of the first embodiment according to the invention.

[FIG. 2] A schematic block diagram of the second embodiment according to the invention.

[FIG. 3] Another configuration of a depolarizing element 54.

[FIG. 4] A schematic block diagram of a conventional polarization combining type pumping light generator.

[FIG. 5] A schematic block diagram of another conventional art.

[Explanation of Reference Numerals]

10, 12: laser diodes

14: polarizing beam splitter

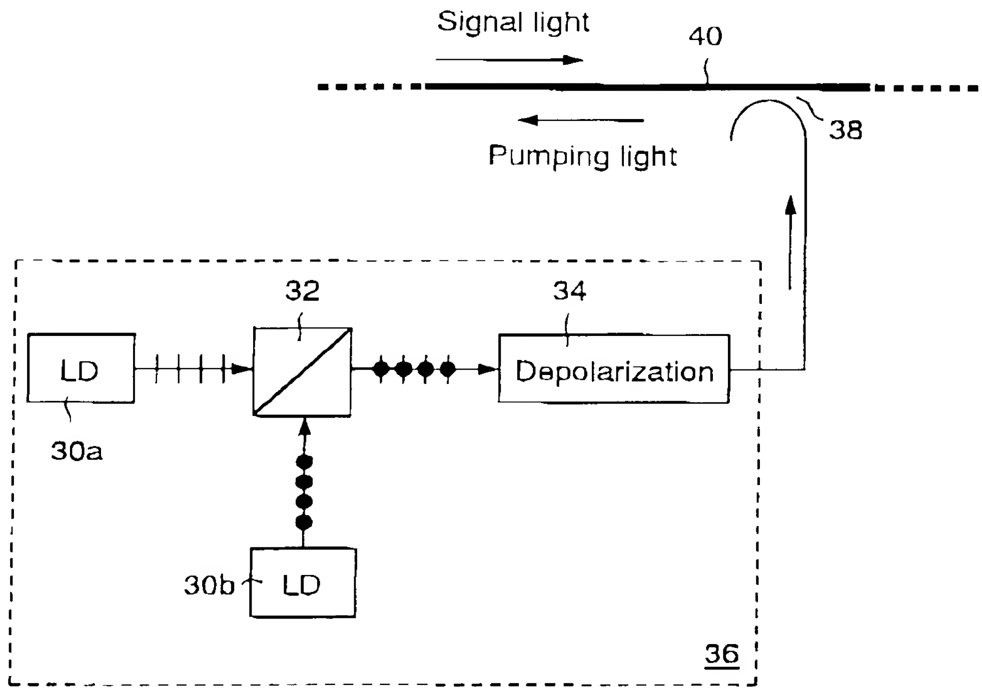
20a, 20b: light sources

22a, 22b: high birefringent optical fibers

24: combiner

30a, 30b: laser diodes
32: polarizing beam splitter
34: depolarizing element
36: pumping light generator
38: optical coupler
40: optical fiber transmission line
50a, 50b: laser diodes
52: combiner
54: depolarizing element
56: pumping light generator
58: optical coupler
60: optical fiber transmission line
63, 64: birefringent mediums

FIG. 1



Signal light
40
38
Pumping light
32
34
LD
Depolarization
30a
30b
LD
36

FIG. 2

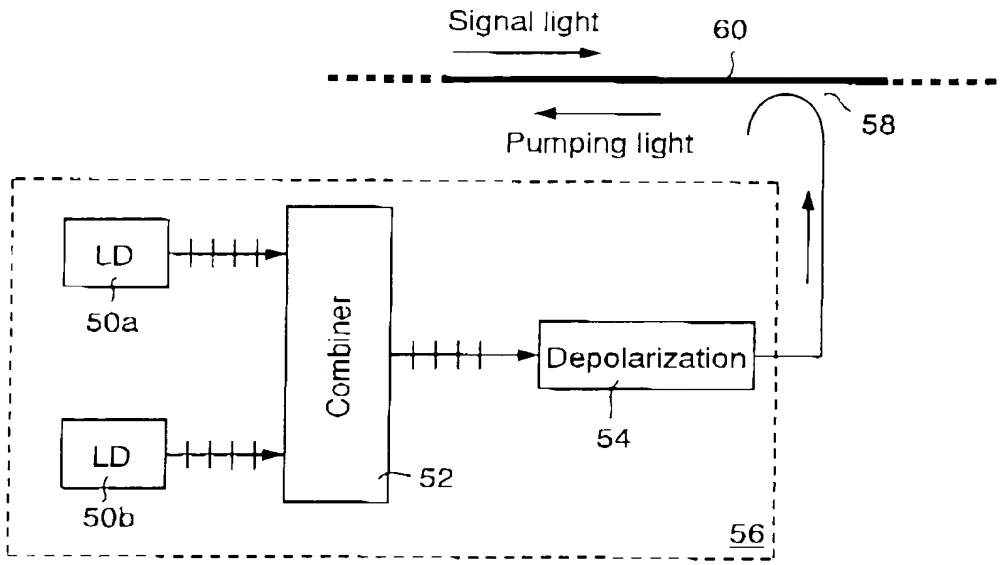

Signal light
60
58
Pumping light
LD
50a
LD
50b
Combiner
52
Depolarization
54
56

FIG. 3

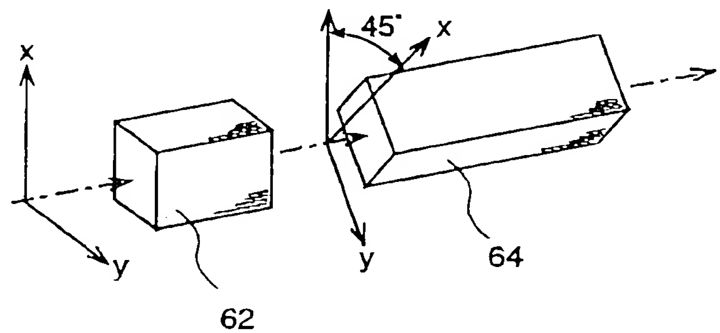


FIG. 4

Prior Art

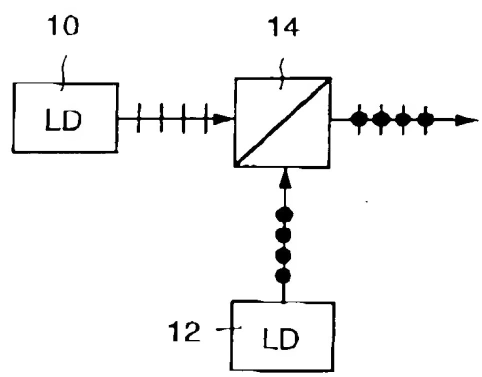
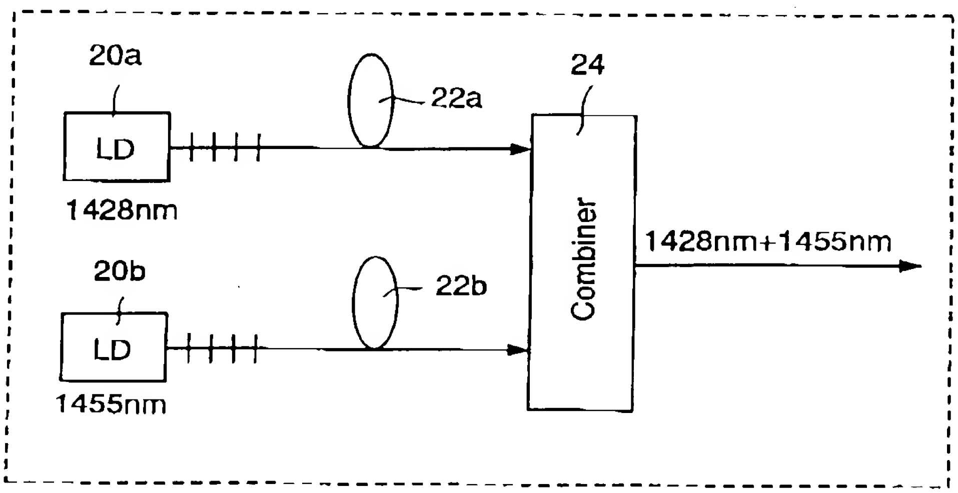



FIG. 5

Prior Art



Japanese Patent Application No. 2000-182164

[Title of Document] Abstract

[Abstract]

[Object] To prevent an increase of a polarization degree of an output pumping light even if one of pumping light sources has failure.

[Solving Means] Laser diodes 30a and 30b are composed of FP-LDs made of InGaAsP to laser-oscillate at 1480 nm band. Output lights from the laser diodes 30a and 30b enter a polarizing splitter 32 in an orthogonal polarization state and are combined there. The light combined by the polarizing splitter 32 enters a depolarizing element 34 to be depolarized there.

[Selected Drawing] Fig. 1